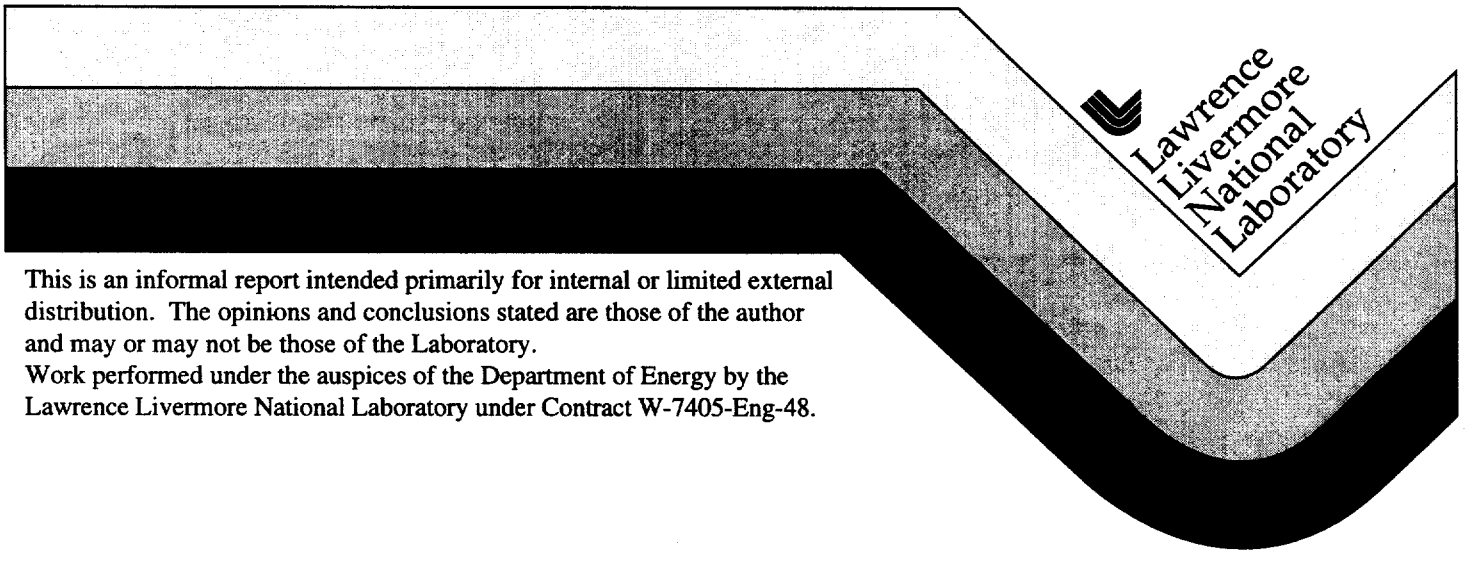
UCRL-ID-128830

Evaluation of Anti-Contamination Garments in Use at LLNL

K.J. Staggs
K.R. Wilson
D.P. Eadens
J.W. Stengel
Y.P. Chong

December 1997



Work performed under the auspices of the Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

DISCLAIMER

Evaluation of Anti-Contamination Garments in Use at LLNL

K.J. Staggs
K.R. Wilson
D.P. Eadens
J.W. Stengel
Y.P. Chong

December 1997

Evaluation of Anti-Contamination Garments in Use at LLNL

Kirk J. Staggs, Kent R. Wilson, Donald P. Eadens
Jerry W. Stengel, and Yee Ping Chong
Lawrence Livermore National Laboratory
PO Box 808, Livermore, CA 94551

ABSTRACT

This paper describes tests conducted on LLNL anti-contamination and clean-room garments using flame exposures derived from federal and industry standards. Each garment was assigned to one of three groups (low, moderate, and high) based on its fire response and performance. Test results and analysis provide guidance in selecting protective clothing for operations involving high temperatures or potential ignition sources.

INTRODUCTION

On February 13, 1997, a fatal accident occurred at the Oak Ridge National Laboratory (ORNL) when a worker's clothing caught fire during a torch-cutting operation. Following this incident, the Hazards Control Department at Lawrence Livermore National Laboratory (LLNL) conducted flammability tests of all anti-contamination and clean-room garments used for operations. Of special concern was the performance of protective clothing used in areas where personnel are exposed to potential ignition sources from operations involving welding, cutting, pyrophoric metals, and other high-energy sources such as lasers. Tests were conducted to determine various parameters (ignition, flame-spread rate, after-burn time, char length, amount of material consumed, and after-glow time) for each garment. The results will provide guidance in the selection of protective clothing best suited for LLNL operations involving high temperatures or potential ignition sources.

TESTING

Twenty-two anti-contamination and clean-room garments were collected from within LLNL. Each garment was assigned a number (1–22), then subdivided alphabetically into sets (e.g., 1A-E; 2A-E; etc.) in order to apply the equivalent flame exposures specified in the American Society for Testing and Materials (ASTM) D-1230 Standard[1] and the Federal Test Method (FTM) 191 Standard.[2] The flame exposure for the ASTM D-1230 Standard is reasonably reproducible, so the number of samples tested for each garment was limited to three. On the other hand, the flame exposure for the FTM 191 Standard is more severe and generally burns faster, so five samples of each garment were tested and the results averaged to account for any variations in the flame-spread rate.

ASTM D-1230 Standard

To create the flame exposure specified in this standard, a small burner was fabricated using a 26-gauge needle. Butane was used as the fuel source, and the flame was adjusted to a length of 5/8 inch (1.59 cm) and controlled with precision valves and pressure gauges. Each sample was then inserted into a specimen holder at a 45° incline, with the flame positioned 3/4 inch (1.91 cm) from the lower end of the test sample. A thread was then placed across the sample (five inches up from the exposed area) to gauge the flame spread. The sample was exposed to the test flame for approximately one second (see Fig. 1).

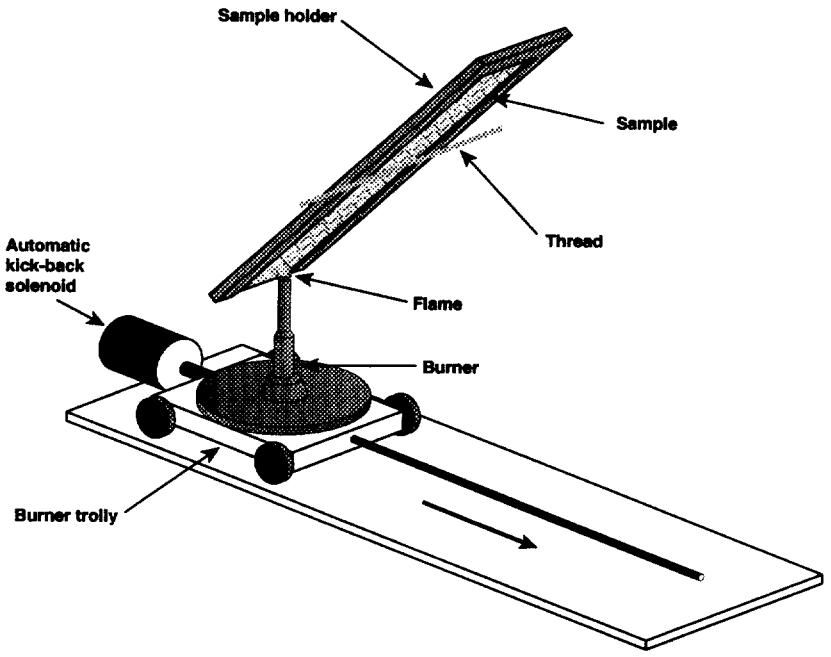


Figure 1. Test apparatus. The sample holder was placed at a 45° angle for samples tested using the ASTM D-1230 flame exposure and at a 90° angle for samples tested using the FTM 191 flame exposure.

Photographs and video records were taken of each test and used to calculate the flame-spread rate as well as other parameters for each sample. In some tests, the lower section of the sample being tested melted or burned but the flame did not extend up to the thread. In these cases, the total area burned or melted was measured and correlated with the length of burn time to derive an omni-directional flame-spread rate (i.e., area/sec). These results can be found in Table A-1, Appendix A.

FTM 191 Standard

The flame exposure for this standard was created using a 3/8-inch (0.95 cm) diameter Bunsen burner, with the vents completely closed, and a special gas mixture as required by the standard. The flame was adjusted to extend approximately 1-1/2 inch (3.81 cm) above the burner. Each sample was then placed in a 3 × 12 inch (7.62 × 30.05 cm) specimen holder and held vertically 3/4 inch (1.91 cm) above the flame. Samples were exposed to the flame for 12 seconds. If ignition occurred, the sample was allowed to burn until either it was consumed or the fire self-extinguished. The burn time was recorded after the flame was removed. If there was any afterglow, it was recorded from the time the flame went out until the glowing stopped. In cases where the afterglow time was lengthy, it was recorded as greater than a minute. A video record was made of each test and used to calculate the measurements for the various parameters. These results can be found in Table A-2, Appendix A.

Char-length measurements were calculated for test samples that did not completely burn. As required by the FTM 191 standard, a 4-ounce weight was attached to the sample corner exposed to the flame while the opposite corner was lifted. The material was allowed to tear (or pull apart) as the weight was lifted. These measurements can also be found in Table A-2, Appendix A.

RANKING PROCESS

The 22 anti-contamination garments tested were categorized into one of three groups (low, moderate, and high) based on their ignition characteristics and flame-spread rates. Table 1 summarizes the garments tested and their group ranking. The criteria used in the ranking process are shown in Table 2. Figures 2 through 4 provide examples of the test results for each group.

The garment's ease of ignition constituted one of the ranking criteria. Ignition was considered to occur if the garment burned for more than one second after flame removal. Brief ignition is defined as obvious burning that self-extinguished within one second of flame removal, while sustained ignition is continued burning for three or more seconds after flame removal. Limited ignition falls between sustained and brief ignition.

Table 1. Anti-contamination garments collected and tested.

Sample	Description	Model/manufacturer	Group
1	Green paper coveralls	Tempro/Kappler	Low
2	Blue paper coveralls	Prevail/Kimberly–Clark	Low
3	Yellow-coated paper coveralls	—[a]	Moderate
4	Blue paper coveralls	Sontara/Durafab	Low
5	Blue- and white-coated paper coveralls	Micro Clean 2-1-2/ Pharmeseal	High
6	White-coated paper coveralls	Tyvek/Kappler	High
7	Blue cloth coveralls	Maximun/Dryden Engineering Co.	High
8	White cloth coveralls	Maximun/Dryden Engineering Co.	High
9	Yellow cloth coveralls	—[a]	Moderate
10	White-coated paper coveralls	—[a]	Moderate
11	100% polypropylene coveralls, style GB-1030	—[a]	Moderate
12	Blue lab coat, 65% polyester and 35% cotton	—[a]	Moderate
13	Orange lab coat, 65% polyester and 35% cotton	Euclid	Moderate
14	Blue lab coat, 50% polyester and 50% cotton	Uniforms Manufacturer, Inc.	Moderate
15	White and orange lab coat	—[a]	Moderate
16	Blue lab coat	—[a]	Moderate
17	Blue lab coat, 65% dacron and 35% cotton	KWB Manufacturing Co.	Moderate
18	White lab coat, 65% polyester and 35% cotton	Best Manufacturing, Inc.	Moderate
19	Yellow cloth coveralls	Defense Apparel, Inc.	Moderate
20	White, full body suit	Tyvek/Kappler	Moderate
21	Orange lab coat, 65% polyester and 35% cotton	Wranglers	High
22	Orange coveralls, 65% polyester and 35% cotton	—[a]	Moderate

[a]Model and manufacturer information was not visible on garment tags.

Table 2. Criteria used for categorizing anti-contamination garments.

IF the garment exhibited	THEN, it was placed in the
• Brief ignition (<1 sec) using the ASTM D-1230 Standard flame exposure and • Limited or brief ignition (<3.0 sec) and a slow flame-spread rate (<0.5 cm/sec) using the FTM 191 Standard flame exposure	*Low group.* This indicates that the garment has a low probability of ignition and a low flame-spread rate.
• Limited ignition (between 1.0 and 3.0 sec) and a moderate flame-spread rate (≤1.0 cm/sec) using the ASTM D-1230 Standard flame exposure and • Sustained ignition (≥3.0 sec) and a moderate flame-spread rate (≤2.0 cm/sec) using the FTM 191 Standard flame exposure	*Moderate group.* This indicates that the garment has a higher probability of ignition than the low group and a moderate flame-spread rate.
• Sustained ignition (≥3.0 sec) and a fast flame-spread rate (>1.0 cm/sec) or thread time (>3.5 secs) using the ASTM D-1230 Standard flame exposure and • A fast flame-spread rate (>2.0 cm/sec) using the FTM 191 Standard flame exposure	*High group.* This indicates that the garment passed the test, but will ignite with a high flame-spread rate.

The other criteria for group ranking involved the flame-spread rate—either linear or area (omni-directional)—over a given time period. A *fast* flame-spread rate for samples tested using the ASTM D-1230 Standard is faster than 1.0 cm per second. At this rate, a flame could travel the full length of a garment at any angle less than 45° from vertical in approximately two minutes. A *fast* flame-spread rate for samples tested using the FTM 191 Standard is faster than 2.0 cm per second, which could be compared to a flame traveling the full length of a garment in just over a minute. Flame-spread rates slower than these are considered to be *moderate*; a flame-spread rate of 0.5 cm or less using the FTM 191 Standard is *slow*.

Garments ranked in the *low* group will not contribute to a fire or allow flames to easily spread. These garments will melt but do not ignite, and if ignited will not burn after the energy source is removed. Garments in the *moderate* group resist ignition, but if ignited will burn slowly. These garments would be suitable for LLNL operations if the user is fully aware of the hazards involved and could easily or quickly sense fire or smoke from the burning garment, allowing time to extinguish the flames. (*Code of Federal Regulation*, Title 29, Part 1910.132(f) requires workers to be trained on the hazards involved in and limitations of selected personal protective equipment.[3]) Garments in the *high* group will ignite with a high flame-spread rate. Therefore, these garments are unsuitable for operations involving high temperature, pyrotechnic operations, welding, or other tasks that might produce a spark, flame, high-energy light source, or incandescent surface.

DISCUSSION

The testing and ranking process did not take into account the burning characteristics of multi-layered clothing. Certain combinations of clothing might burn with more intensity and become difficult to extinguish in a very short time. It is also possible that

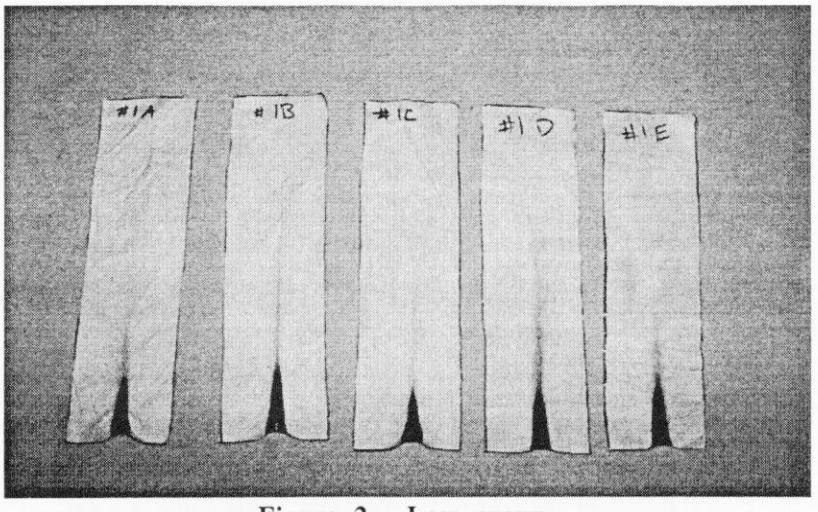


Figure 2. Low group.

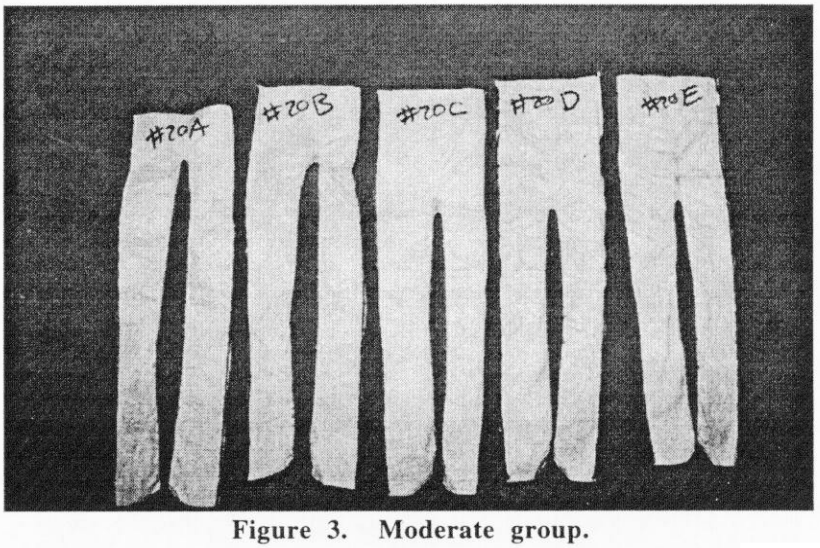


Figure 3. Moderate group.

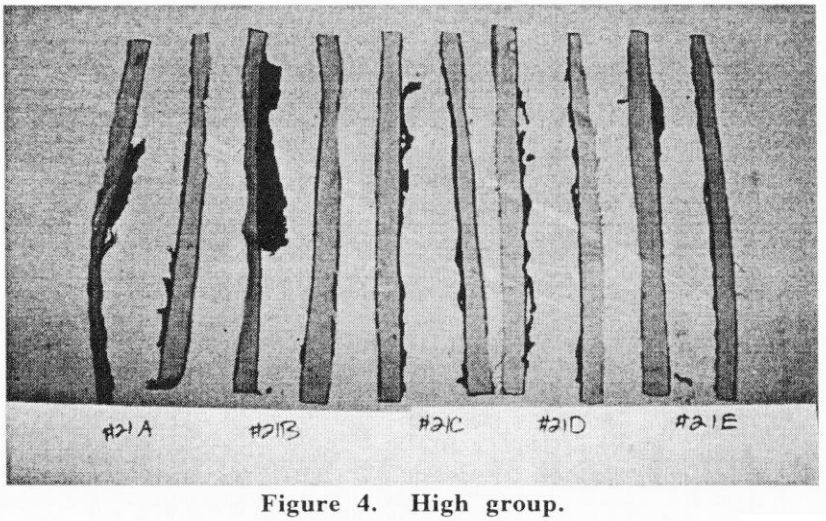


Figure 4. High group.

layering some garments would inhibit fire growth. Thus, careful consideration must be given to garments that melt easily but do not burn. If such garments are the only layer of clothing worn, the intense heat of the melt itself will likely cause skin burns. Furthermore, if these garments are worn over more combustible clothing, the undergarments may dominate fire growth.

In situations where a garment will be exposed to ignition sources, then a fire-resistant garment such as Nomex or Kevlar/PBI should be worn. If this type of garment is too costly for ongoing operations, then overgarments constructed of a lightweight material that will develop minimal flaming if ignited should be worn. Careful consideration should be given to the exposed areas of the user's body (i.e., chin, face, and hands).

Ignition of any garment from open flames, hot slags, or embers will be influenced by factors such as frayed ends, open pockets, crevices, and wrinkles. Frayed ends, particularly around the garment's cuffs, are much easier to ignite. Hot slags or embers trapped in garment folds have more time to elevate the material to ignition temperature. In addition, folds will increase the exposed surface area which can ignite and burn, reinforcing and intensifying the fire. Therefore, garments should be fitted properly with as few folds and wrinkles as possible to help guard against ignition and minimize fire growth. All pockets and cuffs should be sewn shut or removed. Garments that become frayed should be repaired or replaced immediately. Repeated laundering should be limited as much as possible, as this will wear the fabric and remove the chemical fire retardant from fire-retardant cotton coveralls.

CONCLUSION

Flammability tests were conducted at LLNL to determine the fire response and performance of various anti-contamination. Durability, wear, comfort, and other factors were not considered for this study. The results obtained were used to rank various anti-contamination garments into three risk groups (low, moderate, and high), and to provide guidance on selecting garments best suited for use in areas where ignition sources may exist. Garments in the *high* group should not be used in situations where contact with open flame or hot sparks is likely. Those in the *moderate* group should be used with discretion and additional controls. Garments in the *low* group are the most fire resistant and are preferable to those in the previous two groups. However, these may not be safe for use in all areas.

Code of Federal Regulation, Title 29, Part 1910.132(d) requires written hazard assessments to include the selection basis and limitations of personal protective equipment for each task.[3] Thus, careful consideration must be given to both ignition sources and protective equipment needs when selecting garments for work in an area with multiple hazards (e.g., contaminants). In some cases, it may be prudent to use garments made of proven fire-resistant materials (e.g., Nomex, Kevlar/PBI) when conducting welding or pyrotechnic operations. Garments that burn with a low heat-release rate could be used over fire-resistant garments to minimize high replacement costs. Other testing would be required to determine the flammability of such multi-layered garments.

REFERENCES

1. American Society for Testing and Materials, "Standard Test Method for Flammability of Apparel Textiles," ASTM D-1230-85 (1995).
2. General Service Administration, "Federal Standard for Textile Test Methods," Federal Test Method 191A (1978).
3. *Code of Federal Regulations*, Title 29, Part 1910.132, "Personal Protective Equipment—General Requirements," Occupational Safety and Health Administration, U.S. Government Printing Office, Washington DC.

ACKNOWLEDGMENTS

The authors express their gratitude to Steve Leeds, for his technical advice; Mike Trent, for bringing up this subject; Dave Myers, for providing the funding; and the ES&H Team Leaders, for providing the test garments.

APPENDIX A

This appendix contains two tables with data for the samples tested. Table A-1 includes the data for samples tested using the flame exposure for the American Society for Testing and Materials (ASTM) D-1230 Standard. Table A-2 includes the data for samples tested using the flame exposure for Federal Test Method (FTM) 191 Standard.

Table A-1. Results for samples tested using the ASTM D-1230 Standard.

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
1A	B490/491	Low	Green paper coveralls; model: Tempro; manufacturer: Kappler; density: 2.452. Garment in new condition.	0.978	NI	—	—	—
1B	B490/491	Low	Same as above.	1.063	NI	—	—	—
1C	B490/491	Low	Same as above.	1.042	NI	—	—	—
2A	B490/491	Low	Blue paper coveralls; model: Prevail; manufacturer: Kimberly–Clark; density: 2.532. Garment in new condition.	0.971	NI	—	—	—
2B	B490/491	Low	Same as above.	1.044	NI	—	—	—
2C	B490/491	Low	Same as above.	1.042	NI	—	—	—
3A	—[c]	Moderate	Yellow-coated paper coveralls that resemble Durafab; density: 2.102. Garment in new condition.	0.952	BI	0.324	0.734	—
3B	—[c]	Moderate	Same as above.	1.044	LI	0.348	0.569	—
3C	—[c]	Moderate	Same as above.	1.042	LI	0.177	0.356	—
4A	—[d]	Low	Blue paper coveralls; model: Sontara; manufacturer: Durafab; density: 2.626. Garment in new condition.	0.953	NI	—	—	—
4B	—[d]	Low	Same as above.	1.037	NI	—	—	—
4C	—[d]	Low	Same as above.	1.032	NI	—	—	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.
[c]Garment might be from B490/491 or B175.
[d]Garment might be from B175 or B331/332.

Table A-1. Cont'd

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
5A	B490/491	Moderate	Blue- and white-coated paper coveralls; model: Micro Clean 2-1-2; manufacturer: Pharmaseal; density: 1.353. Garment in new condition.	0.969	LI	0.274	1.61	—
5B	B490/491	Moderate	Same as above.	1.044	LI	0.578	1.15	—
5C	B490/491	Moderate	Same as above.	1.026	LI	0.563	0.881	—
6A	B391	Moderate	White-coated paper coveralls; model: Tyvek; manufacturer: Kappler; density: 1.229. Garment in used condition.	0.971	LI	0.105	0.835	—
6B	B391	Moderate	Same as above.	1.035	LI	0.714	0.779	—
6C	B391	Moderate	Same as above.	1.025	LI	0.232	0.958	—
7A	B391	High	Blue cloth coveralls; model: Maximun; manufacturer: Dryden Engineering Co. Garment in slightly used condition.	1	SI	—	3.79	17.7
7B	B391	High	Same as above.	1	SI	—	3.123	13.64
7C	B391	High	Same as above.	1.033	SI	—	3.018	19.62
8A	B391	High	White cloth coveralls; model: Maximun; manufacturer: Dryden Engineering Co. Garment in used condition.	1	SI	—	4.488	11.44
8B	B391	High	Same as above.	1.039	SI	—	5.193	10
8C	B391	High	Same as above.	1.03	SI	—	4.781	9.57

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.

Table A-1. Cont'd

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
9A	—[c]	Low	Yellow cloth coveralls that resemble Defense Apparel, Inc. Garment in used condition.	0.952	NI	—	—	—
9B	—[c]	Low	Same as above.	1.023	NI	—	—	—
9C	—[c]	Low	Same as above.	1.026	NI	—	—	—
10A	—[e]	Moderate	White-coated paper coveralls that resemble Tyvek; density: 1.29. Garment in used condition.	0.947	BI	0.208	0.719	—
10B	—[e]	Moderate	Same as above.	1.029	BI	1.429	0.737	—
10C	—[e]	Moderate	Same as above.	1.006	LI	0.769	0.783	—
11A	Plant Eng	Low	100% Polypropylene coveralls, style GB-1030; density: 1.503. Garment in slightly used condition.	0.947	NI	—	—	—
11B	Plant Eng	Low	Same as above.	1.041	NI	—	—	—
11C	Plant Eng	Low	Same as above.	1.005	NI	—	—	—
12A	B321 A (main bay)	Low	Blue lab coat, 65% polyester and 35% cotton. Garment in worn condition.	0.934	NI	—	—	—
12B	B321 A (main bay)	Low	Same as above.	1.032	NI	—	—	—
12C	B321 A (main bay)	Low	Same as above.	1.032	NI	—	—	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.
[c]Garment might be from B490/491 or B175.
[e]Garment is probably from B361.

Table A-1. Cont'd

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
13A	B321 C (nc shop)[f]	Low	Orange lab coat, 65% polyester and 35% cotton; manufacturer: Euclid. Garment in worn condition.	0.935	NI	—	—	—
13B	B321 C (nc shop)[f]	Low	Same as above.	1.022	NI	—	—	—
13C	B321 C (nc shop)[f]	Low	Same as above.	1.047	NI	—	—	—
14A	B321 A (main bay)	Low	Blue lab coat, 50% polyester and 50% cotton; manufacturer: Uniforms Manufacturer, Inc. Garment in used condition.	0.962	NI	—	—	—
14B	B321 A (main bay)	Low	Same as above.	1.026	NI	—	—	—
14C	B321 A (main bay)	Low	Same as above.	1.032	NI	—	—	—
15A	B321	Low	White and orange lab coat. Garment in badly worn condition.	0.932	NI	—	—	—
15B	B321	Low	Same as above.	1.022	NI	—	—	—
15C	B321	Low	Same as above.	1.014	NI	—	—	—
16A	B321 A (main bay)	Low	Blue lab coat. Garment in worn condition.	0.936	NI	—	—	—
16B	B321 A (main bay)	Low	Same as above.	1.031	NI	—	—	—
16C	B321 A (main bay)	Low	Same as above.	1.031	NI	—	—	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.
[f]nc shop = numerically controlled (special material) machine shop.

Table A-1. Cont'd

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
17A	B321 A (main bay)	Low	Blue lab coat, 65% dacron and 35% cotton; manufacturer: KWB Manufacturing Co. Garment in worn condition.	1.076	NI	—	—	—
17B	B321 A (main bay)	Low	Same as above.	1.032	NI	—	—	—
17C	B321 A (main bay)	Low	Same as above.	1.006	NI	—	—	—
18A	B321 C	Low	White lab coat, 65% polyester and 35% cotton; manufacturer: Best Manufacturing Co. Garment in worn condition.	0.95	NI	—	—	—
18B	B321 C	Low	Same as above.	1.02	NI	—	—	—
18C	B321 C	Low	Same as above.	1.029	NI	—	—	—
19A	B332	Low	Yellow cloth coveralls that resemble Defense Apparel, Inc. Garment in new condition.	0.954	NI	—	—	—
19B	B332	Low	Same as above.	1.024	NI	—	—	—
19C	B332	Low	Same as above.	1.042	NI	—	—	—
20A	B331	Moderate	White, full body suit; model: Tyvek; manufacturer: Kappler; density: 1.324. Garment in new condition.	1.097	LI	0.214	1.232	—
20B	B331	Moderate	Same as above.	1.019	BI	0.6	0.546	—
20C	B331	Moderate	Same as above.	1.031	LI	0.363	1.028	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.

Table A-1. Cont'd

Sample	Location	Group	Description[a]	Length of flame exposure (sec)	Ignition[b]	Linear burn rate (cm/sec)	Omni-directional burn rate (cm/sec)	Thread time (sec)
21A	B321 C	Low	Orange lab coat, 65% polyester and 35% cotton, possibly style 52-RG; manufacturer: Wranglers. Garment in used condition.	0.952	NI	—	—	—
21B	B321 C	Low	Same as above.	1.033	NI	—	—	—
21C	B321 C	Low	Same as above.	1.049	NI	—	—	—
22A	B332	Low	Orange coveralls, 65% polyester and 35% cotton. Garment in used condition.	0.952	NI	—	—	—
22B	B332	Low	Same as above.	1.033	NI	—	—	—
22C	B332	Low	Same as above.	1.005	NI	—	—	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

[b]NI = no ignition; BI = brief ignition; LI = limited ignition; SI = sustained ignition.

Table A-2. Results for samples tested using the FTM 191 Standard.

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
1A	B490/491	Low	Green paper coveralls; model: Tempro; manufacturer: Kappler; density: 2.452. Garment in new condition.	—	—	—	2
1B	B490/491	Low	Same as above.	—	—	—	2.25
1C	B490/491	Low	Same as above.	—	—	—	1.75
1D	B490/491	Low	Same as above.	—	—	—	2
1E	B490/491	Low	Same as above.	—	—	—	2
2A	B490/491	Low	Blue paper coveralls; model: Prevail; manufacturer: Kimberly–Clark; density: 2.532. Garment in new condition.	—	—	—	2
2B	B490/491	Low	Same as above.	—	—	—	2.25
2C	B490/491	Low	Same as above.	—	—	—	2.25
2D	B490/491	Low	Same as above.	—	—	—	2.5
2E	B490/491	Low	Same as above.	—	—	—	2.25
3A	—[b]	Moderate	Yellow-coated paper coveralls that resemble Durafab; density: 2.102. Garment in new condition.	—	—	—	10.5
3B	—[b]	Moderate	Same as above.	—	—	—	8.5
3C	—[b]	Moderate	Same as above.	—	—	—	8.25
3D	—[b]	Moderate	Same as above.	—	—	—	8.5
3E	—[b]	Moderate	Same as above.	—	—	—	9.75
4A	—[c]	Low	Blue paper coveralls, model: Sontara; manufacturer: Durafab; density: 2.626. Garment in new condition.	—	—	—	1.75
4B	—[c]	Low	Same as above.	—	—	—	1.75
4C	—[c]	Low	Same as above.	—	—	—	2.5
4D	—[c]	Low	Same as above.	—	—	—	2.25
4E	—[c]	Low	Same as above.	—	—	—	2.5

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[b]Garment might be from B490/491 or B175.
[c]Garment might be from B175 or B331/332.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
5A	B490/491	Moderate	Blue- and white-coated paper coveralls; model: Micro Clean 2-1-2; manufacturer: Pharmaseal; density: 1.353. Garment in new condition.	—	—	—	10.5
5B	B490/491	High	Same as above.	—	—	—	11
5C	B490/491	High	Same as above.	—	—	—	10.75
5D	B490/491	Moderate	Same as above.	—	—	—	9.5
5E	B490/491	High	Same as above.	—	—	—	11
6A	B391	High	White-coated paper coveralls; model: Tyvek; manufacturer: Kappler; density: 1.229. Garment in used condition.	—	—	—	12
6B	B391	High	Same as above.	—	—	—	11.75
6C	B391	High	Same as above.	—	—	—	11
6D	B391	Moderate	Same as above.	—	—	—	10.5
6E	B391	High	Same as above.	—	—	—	11.5
7A	B391	Moderate	Blue cloth coveralls; model: Maximun; manufacturer: Dryden Engineering Co. Garment in slightly used condition.	—	9	—[d]	—
7B	B391	Moderate	Same as above.	—	9	—[d]	—
7C	B391	Moderate	Same as above.	—	6	—[d]	—
7D	B391	Low	Same as above.	—	—	—	—
7E	B391	Moderate	Same as above.	0.598	26	—	—
8A	B391	Moderate	White cloth coveralls; model: Maximun; manufacturer: Dryden Engineering Co. Garment in used condition.	0.7257	12	—	—
8B	B391	Moderate	Same as above.	1.27	43	—	—
8C	B391	Moderate	Same as above.	1.693	17	—	—
8D	B391	Moderate	Same as above.	1.693	30	—	—
8E	B391	Moderate	Same as above.	1.494	21.2	—	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[d]No forward propagation of flame after source removal.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
14A	B321 A (main bay)	Moderate	Blue lab coat, 50% polyester and 50% cotton; manufacturer: Uniforms Manufacturer, Inc. Garment in used condition.	0.9407	34	84	—
14B	B321 A (main bay)	Moderate	Same as above.	—	41	104	—
14C	B321 A (main bay)	Moderate	Same as above.	1.134	39	69	—
14D	B321 A (main bay)	Moderate	Same as above.	1.129	38	85	—
14E	B321 A (main bay)	Moderate	Same as above.	1.954	35	76	—
15A	B321	Moderate	White and orange lab coat. Garment in badly worn condition.	1.847	30	4	—
15B	B321	High	Same as above.	2.3813	23	—	—
15C	B321	Moderate	Same as above.	1.868	24	—	—
15D	B321	Moderate	Same as above.	1.639	21	6	—
15E	B321	Moderate	Same as above.	1.764	25	2	—
16A	B321 A (main bay)	Moderate	Blue lab coat. Garment in worn condition.	1.639	40	20	—
16B	B321 A (main bay)	Moderate	Same as above.	1.104	33	21	—
16C	B321 A (main bay)	Moderate	Same as above.	1.129	33	19	—
16D	B321 A (main bay)	Moderate	Same as above.	1.21	34	13	—
16E	B321 A (main bay)	Moderate	Same as above.	1.27	44	29	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
12A	B321 A (main bay)	Moderate	Blue lab coat, 65% polyester and 35%. Garment in worn condition.	0.5644	41	7	—
12B	B321 A (main bay)	Moderate	Same as above.	0.5522	57	—	—
12C	B321 A (main bay)	Moderate	Same as above.	0.8944	45	22	—
12D	B321 A (main bay)	Moderate	Same as above.	0.7144	40	8	—
12E	B321 A (main bay)	Moderate	Same as above.	0.5976	54	5	—
13A	B321 C (nc shop)[f]	Moderate	Orange lab coat, 65% polyester and 35% cotton; manufacturer: Euclid. Garment in worn condition.	0.7362	52	9	—
13B	B321 C (nc shop)[f]	Moderate	Same as above.	1.134	35	12	—
13C	B321 C (nc shop)[f]	Moderate	Same as above.	1.058	38	14	—
13D	B321 C (nc shop)[f]	Moderate	Same as above.	1.2451	41	18	—
13E	B321 C (nc shop)[f]	Moderate	Same as above.	1.2451	38	19	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.
[f]nc shop = numerically controlled (special material) machine shop.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
14A	B321 A (main bay)	Moderate	Blue lab coat, 50% polyester and 50% cotton; manufacturer: Uniforms Manufacturer, Inc. Garment in used condition.	0.9407	34	84	—
14B	B321 A (main bay)	Moderate	Same as above.	—	41	104	—
14C	B321 A (main bay)	Moderate	Same as above.	1.134	39	69	—
14D	B321 A (main bay)	Moderate	Same as above.	1.129	38	85	—
14E	B321 A (main bay)	Moderate	Same as above.	1.954	35	76	—
15A	B321	Moderate	White and orange lab coat. Garment in badly worn condition.	1.847	30	4	—
15B	B321	High	Same as above.	2.3813	23	—	—
15C	B321	Moderate	Same as above.	1.868	24	—	—
15D	B321	Moderate	Same as above.	1.639	21	6	—
15E	B321	Moderate	Same as above.	1.764	25	2	—
16A	B321 A (main bay)	Moderate	Blue lab coat. Garment in worn condition.	1.639	40	20	—
16B	B321 A (main bay)	Moderate	Same as above.	1.104	33	21	—
16C	B321 A (main bay)	Moderate	Same as above.	1.129	33	19	—
16D	B321 A (main bay)	Moderate	Same as above.	1.21	34	13	—
16E	B321 A (main bay)	Moderate	Same as above.	1.27	44	29	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
17A	B321 A (main bay)	Moderate	Blue lab coat, 65% dacron and 35% cotton; manufacturer: KWB Manufacturing Co. Garment in worn condition.	1.451	49	34	—
17B	B321 A (main bay)	Moderate	Same as above.	0.9676	42	17	—
17C	B321 A (main bay)	Moderate	Same as above.	1.089	39	25	—
17D	B321 A (main bay)	Moderate	Same as above.	1.176	94	39	—
17E	B321 A (main bay)	Moderate	Same as above.	0.7471	36	31	—
18A	B321 C	High	White lab coat, 65% polyester and 35% cotton; manufacturer: Best Manufacturing Co. Garment in worn condition.	2.117	27	22	—
18B	B321 C	Moderate	Same as above.	1.524	24	30	—
18C	B321 C	High	Same as above.	2.54	23	11	—
18D	B321 C	Moderate	Same as above.	1.588	25	5	—
18E	B321 C	Moderate	Same as above.	1.671	25	7	—
19A	B332	Moderate	Yellow cloth coveralls that resemble Defense Apparel, Inc. Garment in used condition.	1.451	36	37	—
19B	B332	Moderate	Same as above.	1.8143	35	25	—
19C	B332	Moderate	Same as above.	1.693	36	36	—
19D	B332	Moderate	Same as above.	1.958	35	47	—
19E	B332	Moderate	Same as above.	2.048	34	25	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.

Table A-2. Cont'd

Sample	Location	Group	Description[a]	Burn rate (cm/sec)	Afterburn time (sec)	Afterglow time (sec)	Char length (in.)
20A	B331	Moderate	White, full body suit; model: Tyvek; manufacturer: Kappler; density: 1.324. Garment in new condition.	—	—	—	10
20B	B331	Moderate	Same as above.	—	—	—	9.25
20C	B331	Moderate	Same as above.	—	—	—	8
20D	B331	Moderate	Same as above.	—	—	—	7.75
20E	B331	Moderate	Same as above.	—	—	—	7.75
21A	B321 C	High	Orange lab coat, 65% polyester and 35% cotton, possibly style 52-RG; manufacturer: Wranglers. Garment in used condition.	2.032	29	8	—
21B	B321 C	Moderate	Same as above.	1.355	21	6	—
21C	B321 C	High	Same as above.	2.177	24	3	—
21D	B321 C	High	Same as above.	2.628	18	6	—
21E	B321 C	High	Same as above.	3.266	28	4	—
22A	B332	Moderate	Orange coveralls, 65% polyester and 35% cotton. Garment in used condition.	0.847	48	6	—
22B	B332	Moderate	Same as above.	0.577	39	6	—
22C	B332	Moderate	Same as above.	0.693	44	12	—
22D	B332	Moderate	Same as above.	0.896	40	7	—
22E	B332	Moderate	Same as above.	0.747	44	5	—

[a]Some anti-contamination garments were badly worn or had no visible manufacturer's tag. Therefore, the model, manufacturer, or fabric content could not be provided for all samples.